Improving Formulation of Marine Stable Boundary Layers Using CBLAST Weak Wind Data

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LONG-TERM GOAL

The long-term goals are to better understand air-sea exchange of momentum, heat and moisture and its impact on the marine boundary layer and to better understand the influence of SST variations on the area-averaged (grid-averaged) flux-gradient relationship.   Substantial modification of the formulation of the surface moisture flux for all conditions and the boundary layer for very stable conditions are also long term goals.

OBJECTIVES

The objectives are to quantify the influences of surface heterogeneity and strong stability on the transfer coefficients for the bulk formula and to formulate the difference between the transfer coefficients for momentum, heat and moisture.

APPROACH

Analyze the LongEZ eddy-correlation data in the CBLAST Weak Wind Pilot Experiment 2001 and compare with eddy-correlation data from the CBLAST WHOI ASIT tower during the intensive period and prior to the intensive period. LongEZ data from SHOWEX will be incorporated for comparison. We will also analyze eddy-correlation data collected by the CIRPAS Pelican during the CBLAST Weak Wind Experiment.   The analyzed fluxes will be used for evaluation of regional modeling and LES simulations.

WORK COMPLETED

Work during the past year concentrated on examination of the wind and stress variability in the cases of weakest winds. We have also carried out joint work with Shouping Wang. We have developed a new roughness length formulation, which Shouping has tested in COAMPS. A short paper has been submitted to Geophysical Review Letters. We have not been unable to obtain the corrected data from the ASIT tower.

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RESULTS

With very weak winds, the wind and stress fields become dominated by background mesoscale motions, generally of unknown origin. For weak large-scale, the wind direction meanders in an unpredictable manner. This meandering often takes the form of sudden wind direction shifts in contrast to conventional understanding. A modified bulk formula has been developed, but much more evaluation is required before offering it to the modeling community. Numerical models do not capture such motions not only because of resolution issues, but also because such motions on resolved scales are seriously damped by explicit and implicit numerical horizontal diffusion required for well behaved numerical performance. In actuality, such mesoscale motions lead to shear-generation of turbulence and enhanced surface fluxes. In CBLAST Low, such mesoscale motions become important when the large-scale flow at 10 m decreases to less than 2 m/s. While such winds occur less than 10% of the time, they often lead to fog development. The large wind direction variability (Figure 1) prevents adjustment of the wind driven wave field, which is superimposed upon the normally larger-amplitude swell.

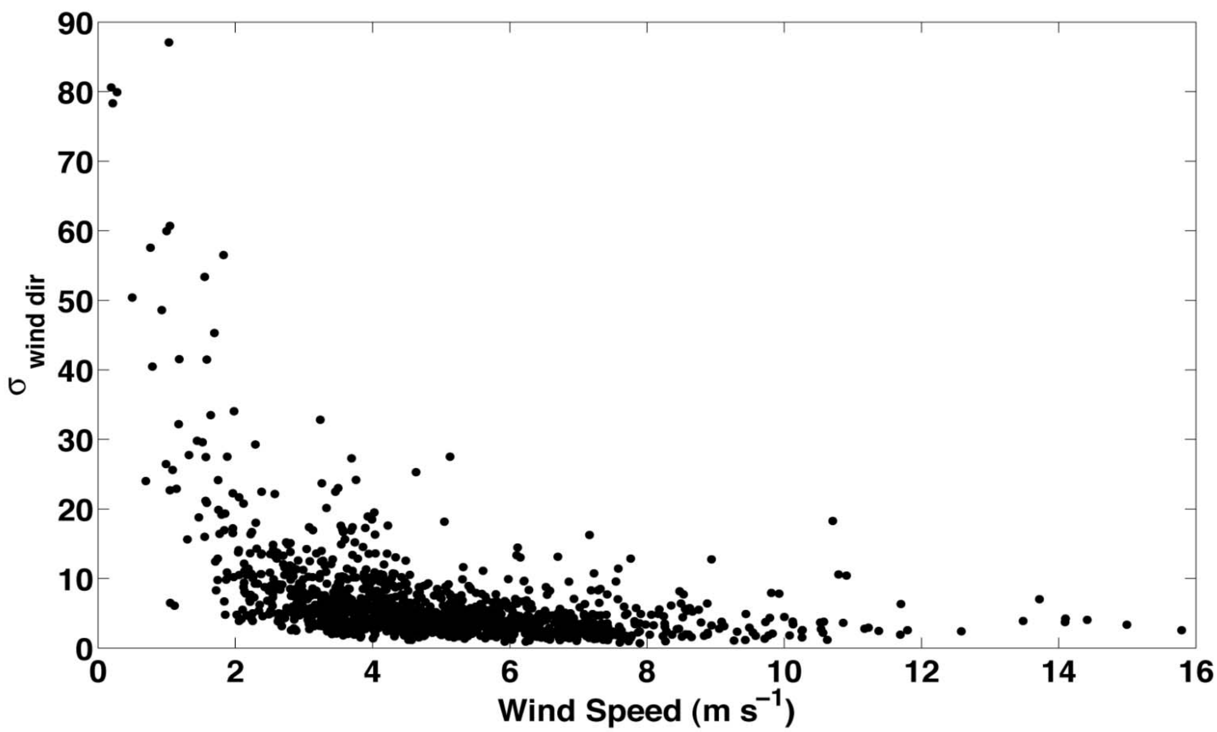

Figure 1. The standard deviation of the one-minute wind direction within one-hour records at the ASIT Tower. The mathematical upper limit of the standard deviation of wind direction is 104 degrees. Some weak-wind cases were eliminated because of fog formation and condensation on the sensors.

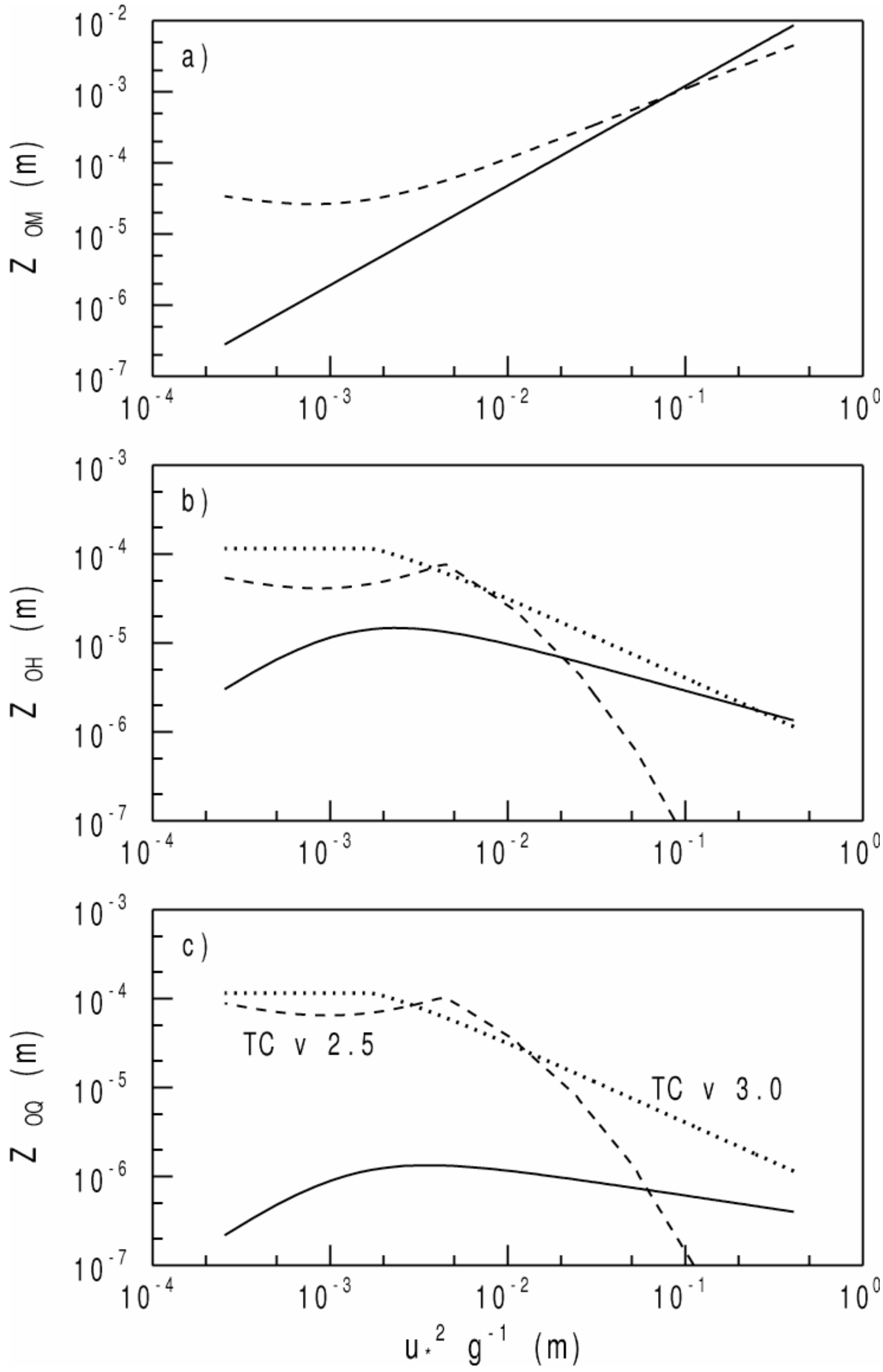

Figure 2. Roughness lengths for a) momentum, b) heat and c) moisture for the new formulation (solid curves), COARE v 2.5 (dashed) and COARE v 3.0 (dotted).

New formulations of the roughness lengths for momentum, heat and moisture were developed for the standard bulk flux formula with Monin-Obukov similarity theory (Vickers et al., 2007). The new formulations are based on turbulence measurements collected by the NOAA LongEZ in CBLAST Low and SHOWEX. The proposed roughness lengths are generally smaller than existing formulations, especially for moisture transport. Significant improvement is found for the latent heat flux compared to existing algorithms used by the COAMPS surface flux scheme and in the TOGA COARE v 2.5 and v 3.0 bulk flux algorithms. The reduced latent heat flux was verified using ASIT tower data (unpublished).

The more efficient transfer of heat compared to moisture is apparently related to the dynamic nature of temperature and the fact that temperature fluctuations dominate buoyancy generation of turbulence for our datasets. The proposed momentum roughness length (and thus the momentum flux) is smaller than given by existing algorithms in conditions of modestly weak winds and weak turbulence partly because of numerous cases of wind following swell. The proposed formulations need to be tested using independent datasets. The proposed formulation did not include the very weakest wind cases where the wind field is dominated by meandering mesoscale motions and the drag coefficient (roughness length for momentum) is apparently augmented by such motions.

RELATED PROJECTS

We are currently constructing a new surface flux scheme for Eric Skyllingstad's LES model with the option for a TOGA COARE 2.6a -like method that includes the Charnock term plus a smooth flow term, and LKB roughness lengths for heat and moisture.

PUBLICATIONS

Vickers, D. and L. Mahrt, 2006: Evaluation of the air-sea bulk formula and sea-surface temperature variability. *J. Geophys. Res.* 111, 5002-5016. [published, refereed]

Skyllingstad, S., D. Vickers, L. Mahrt and R. Samelson, 2006: Effects of Mesoscale Sea-Surface Temperature Fronts on the Marine Boundary Layer. *Boundary-Layer Meteorol.*, 123, 219-237. [published, refereed]

Mahrt L. 2007: Weak-wind mesoscale meandering in the nocturnal boundary layer. *Env. Fluid Mech.*, 7, 331-347. [published, refereed]

Vickers, D., L. Mahrt and S. Wang, 2007: New formulations for sea-surface roughness lengths. Submitted to *Geophy. Res. Letters*. [refereed]